DOCUMENT RESUME

ED 260 122 TM 850 449

AUTHOR Mitchell, Karen Janice
TITLE Cognitive Processing Determinants of Item Difficulty on the Verbal Subtests of the Armed Services Vocational Aptitude Battery.
INSTITUTION Army Research Inst. for the Behavioral and Social Sciences, Arlington, Va.
REPORT NO ARI-TR-598
PUB DATE Nov 83
NOTE 51p.
PUB TYPE Reports - Research/Technical (143)

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS Adults; Aptitude Tests; *Cognitive Processes; *Difficulty Level; Enlisted Personnel; *Item Analysis; *Latent Trait Theory; Models; *Occupational Tests; Personnel Evaluation; Reading Comprehension; Test Items; Test Validity; Verbal Ability; *Verbal Tests; Vocabulary
IDENTIFIERS *Armed Services Vocational Aptitude Battery; Rasch Model

ABSTRACT

A model of verbal performance was developed which defined cognitive processes thought to underlie performance on the Word Knowledge and Paragraph Comprehension subtests of the Armed Services Vocational Aptitude Battery (ASVAB). The items from two forms of these ASVAB verbal subtests were rated on five conceptualized cognitive storage processes: (1) perceptual processing; (2) executive or control processing; (3) short term storage--lexical access semantic, and syntactic analysis; (4) long-term storage of information structures; and (5) selection and execution of the response. The relative effects of the cognitive dimensions on Rasch model item difficulties were assessed for eight groups of army applicants and personnel, using linear logistic latent trait methods. Analyses suggested that these cognitive processing variables were related to item difficulty. The logistic latent trait models predicted from 17 to 30 percent of the variance in the item difficulty values estimated by the Rasch models for the word knowledge items. However, results for the paragraph comprehension items were inconclusive. Sample test items are included. (GDC)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

TM

ED260122

Technical Report 598

Cognitive Processing Determinants of Item Difficulty on the Verbal Subtests of the Armed Services Vocational Aptitude Battery

Karen Janice Mitchell

Selection and Classification Technical Area
Manpower and Personnel Research Laboratory

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
X This document has been reproduced as received from the person or organization originating it.
[ ] Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

U. S. Army

Research Institute for the Behavioral and Social Sciences

November 1983

Approved for public release; distribution unlimited.

BEST COPY AVAILABLE

TM 850 449

U. S. ARMY RESEARCH INSTITUTE
FOR THE BEHAVIORAL AND SOCIAL SCIENCES

A Field Operating Agency under the Jurisdiction of the

Deputy Chief of Staff for Personnel

EDGAR M. JOHNSON
Technical Director

L. NEALE COSBY
Colonel, IN
Commander

Technical review by

Michael G. Rumsey
Clessen J. Martin
Paul van Rijn

NOTICES

DISTRIBUTION: Primary distribution of this report has been made by ARI. Please address correspondence concerning distribution of reports to: U.S. Army Research Institute for the Behavioral and Social Sciences, ATTN: PERI-POT, 5001 Eisenhower Avenue, Alexandria, Virginia 22333-5600.

FINAL DISPOSITION: This report may be destroyed when it is no longer needed. Please do not return it to the U.S. Army Research Institute for the Behavioral and Social Sciences.

NOTE: The findings in this report are not to be construed as an official Department of the Army position, unless so designated by other authorized documents.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Technical Report 598	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Cognitive Processing Determinants of Item Difficulty on the Verbal Subtests of the Armed Services Vocational Aptitude Battery		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Karen J. Mitchell		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Ave., Alexandria, VA 22333-5600		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 2Q263731A792
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Research Institute for the Behavioral and Social Sciences, 5001 Eisenhower Ave., Alexandria, VA 22333-5600		12. REPORT DATE November 1983 13. NUMBER OF PAGES 12
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

ASVAB	Information Processing
Selection	Cognitive Psychology
Classification	Verbal Processing
Ability Testing	Latent Trait Theory

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The purpose of this research was to identify the cognitive processing operations, stores, and strategies involved in performance on the verbal subtests of the Armed Services Vocational Aptitude Battery (ASVAB) 8/9/10. The project was conducted in two parts.

The research began with a review of recent work in verbal information processing. A model of verbal performance was developed as a conceptual framework for identifying and operationalizing process-

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

BEST COPY

ing components. Theoretical and operational definitions were drafted for cognitive processes thought to underlie performance on the ASVAB Word Knowledge (WK) and Paragraph Comprehension (PC) subtests. The operational definitions were used to rate the WK and PC items on two ASVAB forms.

In Part two, item response data were modeled for eight groups Fiscal Year 1981 Army applicants and accessions using Rasch and Linear Logistic Latent Trait (LLLT) methods. The relative effects of the operationalized verbal processes on item difficulty were determined using the LLLT algorithms. For the WK subtests, variables indexing the amount of information presented by an item and the usage frequency of the target and response words had sizable effects. Results for the PC subtests were inconclusive. There was evidence that propositional density and inference construction variables were related to difficulty for the PC items.

The relations of cognitive processing variables to item difficulty for the ASVAB Word Knowledge and Paragraph Comprehension subtests were demonstrated. These results were used in subsequent analyses of the predictive validity of assessed ability components to successful performance in Army jobs. The model-building procedures were proposed for general use in assessing and documenting cognitive processing contributions to performance on tests and test-like tasks. The procedures that were developed were proposed for use in constructing industrial/organizational assessment instruments that tap training- and job-relevant processing abilities.

Technical Report 598

Cognitive Processing Determinants of Item Difficulty on the Verbal Subtests of the Armed Services Vocational Aptitude Battery

Karen Janice Mitchell

Submitted by
Newell K. Eaton, Chief
Selection and Classification Technical Area

Approved as technically adequate
and submitted for publication by
Joyce L. Shields, Director
Manpower and Personnel
Research Laboratory

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

Office, Deputy Chief of Staff for Personnel
Department of the Army

November 1983

Army Project Number
2Q263731A792

Manpower and Personnel

Approved for public release; distribution unlimited.

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The Selection & Classification Technical Area of the Army Research Institute for the Behavioral & Social Sciences (ARI) is concerned with developing effective procedures for the selection of applicants into military service and for the classification of accessions into Army occupational specialities. The purpose of this research was to examine and document the construct validity of the verbal subtests of the current Department of Defense military selection and classification battery, the Armed Services Vocational Aptitude Battery (ASVAB) 8/9/10.

Edgar M. Johnson

EDGAR M. JOHNSON
Technical Director

COGNITIVE PROCESSING DETERMINANTS OF ITEM DIFFICULTY
ON THE VERBAL SUBTESTS OF THE ARMED SERVICES
VOCATIONAL APTITUDE BATTERY

BRIEF

Requirement:

To identify the cognitive processing operations, stores, and strategies involved in performance on the verbal subtests of the Armed Services Vocational Aptitude Battery (ASVAB) 8/9/10.

Procedure:

Cognitive dimensions thought to underlie performance on the ASVAB Word Knowledge (WK) and Paragraph Comprehension (PC) items were operationlized; the verbal items on two ASVAB forms were rated on these variables. The relative effects of the cognitive dimensions on Rasch item difficulties were assessed for eight groups of FY81 Army applicants and accessions using Linear Logistic Latent Trait methods.

Findings:

Analyses suggested that cognitive processing variables were related to item difficulty for FY81 applicants and accessions on the ASVAB 8/9/10 verbal subtests. The LLLT models predicted from 17% to 30% of the variance in the item difficulty values estimated by the Rasch models for the WK items. The results for the PC items were inconclusive.

Utilization of Findings:

The relevance of cognitive processing variables to item difficulty for the ASVAB 8/9/10 WK and PC subtests was demonstrated. Further examination of the predictive utility of these and similar constructs to success in Army training and military jobs is needed. Analyses of this type will enable assessment and documentation of the construct validity of ASVAB subtests. These methods can be used to develop item sets so that specified training- and job-relevant processing abilities are tapped.

COGNITIVE PROCESSING DETERMINANTS OF ITEM DIFFICULTY
ON THE VERBAL SUBTESTS OF
THE ARMED SERVICES VOCATIONAL APTITUDE BATTERY

CONTENTS

Page

ABSTRACT 1

INTRODUCTION 1

METHOD 2

The Armed Services Vocational Aptitude Battery . . . 3
The Word Knowledge Subtest 3
The Paragraph Comprehension Subtest 3

Part One 8
The Development of a Model of Verbal Performance . 8
WK and PC Item Rating Scheme 12

Part Two 14

RESULTS 16

Development of the Word Knowledge Model 16
Cognitive Component Variables 21
Form Differences 22
Group Differences 22

Development of the Paragraph Comprehension Models . . 23

DISCUSSION 28

Relevance of Cognitive Processing Variables to Item Difficulty 28
Determinations of the Parallelism of the Operational Forms 28

CONCLUSION 29

REFERENCES 31

LIST OF TABLES

Page

Table

1. ASVAB 8/9/10 Subtests 4
2. Instructions and Sample Items from the Word Knowledge Subtest 6
3. Instructions and Sample Items from the Paragraph Comprehension Subtest 7
4. Verbal Performance Model 9
5. Part Two Applicant Sample Sizes 15
6. Full Model Cognitive Component Parameters: Word Knowledge, Form One 17
7. Reduced Model Cognitive Component Parameters: Word Knowledge, Form One 18
8. Full Model Cognitive Component Parameters: Word Knowledge, Form Two 19
9. Reduced Model Cognitive Component Parameters: Word Knowledge, Form Two 20
10. Full Model Cognitive Comonent Parameters: Paragraph Comprehension, Form One 24
11. Reduced Model Cognitive Component Parameters: Paragraph Comprehension, Form One 25
12. Full Model Cognitive Component Parameters: Paragraph Comprehension, Form Two 26
13. Reduced Model Cognitive Component Parameters: Paragraph Comprehension, Form Two 27

COGNITIVE PROCESSING DETERMINANTS OF VERBAL ITEM DIFFICULTY ON THE ARMED SERVICES VOCATIONAL APTITUDE BATTERY

ABSTRACT

Research was designed to identify cognitive processing operations and strategies involved in performance on the verbal subtests of the Armed Services Vocational Aptitude Battery (ASVAB). Cognitive processes thought to underlie performance on the Word Knowledge and Paragraph Comprehension subtests were identified. Items on two ASVAB forms were rated on these variables. The relative effects of cognitive processes were examined for eight groups of Army Applicants and Accessions using Linear Latent Logistic Trait methods. Analyses demonstrated the relevance of cognitive processing variables to item difficulty for the ASVAB verbal items.

INTRODUCTION

The purpose of this research was to identify the cognitive processing operations, stores, and strategies involved in performance on the verbal subtests of the Armed Services Vocational Aptitude Battery (ASVAB) 8/9/10. Procedures were developed for evaluating the underlying cognitive ability contributions to performance on item sets. The methods were proposed for general use in assessing and documenting cognitive processing contributions to performance on tests and test-like tasks. The procedures that were developed were proposed for use in constructing industrial/organizational assessment instruments that tap specified, training- and job-relevant processing abilities.

The specific objective of this work was to clarify the construct validity of verbal items on ASVAB 8/9/10. These results were used in subsequent analyses of the predictive validity of assessed ability components to successful performance in Army jobs. The research was conducted in two parts.

METHOD

Part 1 began with a review of recent work in the area of verbal information processing. The review was directed at identifying possible sources of cognitive processing operation, store, and strategy differences on the verbal items of ASVAB and suggesting methodological alternatives for the examination of relevant data. Part 1 activities included:

A. Conducting a review of the definition and measurement of cognitive processing components involved in performance on verbal tasks.

B. Developing a model of verbal performance to provide a conceptual framework for identifying and operationalizing processing components.

C. Drafting theoretical and operational definitions for the ability components deemed relevant to performance on the Word Knowledge (WK) and Paragraph Comprehension (PC) items of ASVAB.

D. Coding the Word Knowledge and Paragraph Comprehension items on two ASVAB 8/9/10 forms for the presence or absence, complexity, or frequency of execution for each cognitive ability component.

Part 1 methods were based on the premise that variation in item difficulty would be a function of the type and level of required processing. It was also posited that processing requirements could be accounted for by structural features of items and that processing requirements could be indexed or quantified accordingly.

Part 2 analyses examined the ability component contributions to item and person variance on the verbal items of ASVAB. Part 2 activities included:

A. Modeling item difficulty for the Word Knowledge and Paragraph Comprehension items for Fiscal Year 1981 Army Applicants and Accessions using linear logistic latent trait techniques; stimulus complexity data reflecting the nature or level of involvement for relevant cognitive processing operations and performance data for selected samples of examinees fed into the models.

B. Cross validating the models across ASVAB forms and samples of examinees.

A description of the operational Armed Services Vocational Aptitude Battery (ASVAB) follows.

The Armed Services Vocational Aptitude Battery.

The Armed Services Vocational Aptitude Battery (ASVAB) was introduced in January 1976 as the single Department of Defense selection and classification battery. Six replacement forms were developed and implemented October 1, 1980. The 1980 version, ASVAB 8/9/10, was the focus of this work.

The ASVAB is administered to over one million applicants for military service each year. The ASVAB plays two important roles in the enlistment of military personnel. First, ASVAB scores are used in determining an applicant's eligibility for military service. Second, ASVAB scores are used to establish an individual's eligibility for assignment to specific military jobs.

The ASVAB consists of eight power and two speed tests. The ten subtests are listed in Table 1. These subtests are included because research and experience have demonstrated that they are valid predictors of success in various types of military jobs.

Table 1 also provides the number of items per subtest and the testing time limits. Although all ten subtests are individually timed, only Numerical Operations and Coding Speed are considered speed tests. The remaining eight subtests are power tests with ample time limits.

The means and standard deviations included in Table 1 were computed for the subtest raw scores of a random sample of FY81 Army Applicants described in Kass, Mitchell, Grafton, and Wing (1981). Estimates of subtest internal consistency reliabilities for the eight power subtests for each of the six forms of ASVAB 8/9/10 were derived from Ree, Mullins, Mathews and Massey (1981). Parallel form reliability estimates for the two speeded subtests were obtained from Sims and Hiatt (1981) and Wilfong (1980).

The Word Knowledge Subtest

There are thirty-five items on the Word Knowledge subtest of the operational ASVAB. The test is constructed to assess the examinee's understanding of the meaning of words. Surface characteristic differences associated with stem and alternatives for the vocabulary items include: word frequency, vocabulary level, number of syllables, grammatical class, stem type, etc. Instructions and sample items from the Word Knowledge subtest appear at Table 2.

The Paragraph Comprehension Subtest

The ASVAB 8/9/10 Paragraph Comprehension subtest has fifteen items. The subtest is constructed to assess the examinee's understanding of the meaning of paragraphs. Surface characteris-

TABLE 1
ASVAB 8/9/10 Subtests

Subtest Name	Description	Number of Items	Test Time (min.)	20% of Army Applicants for FY81 Mean	20% of Army Applicants for FY81 Standard Deviation	Reliability
General Science (GS)	A power test assessing knowledge of the physical and biological sciences	25	11	14.3[d]	5.2	.86[a]
Arithmetic Reasoning (AR)	Word problems emphasizing mathematical reasoning rather than mathematical knowledge	30	36	16.4	6.8	.91
Word Knowledge (WK)	A power test assessing knowledge of word meanings	35	11	23.1	7.9	.92
Paragraph Comprehension (PC)	A power test assessing understanding of the meaning of paragraphs	15	13	9.7	3.5	.8[illegible]
Numerical Operations (NO)	A speeded test of addition, subtraction, multiplication and division	50	3	34.2	10.5	.78[b]
Coding Speed (CS)	A speeded test of facility at matching word and number codes	84	7	42.8	15.1	.85[c]
Auto Shop Information (AS)	A power test assessing knowledge of auto mechanics, shop practices and tool functions	25	11	14.6	5.7	.87
Mathematics Knowledge (MK)	A power test assessing knowledge of algebra, geometry and fractions	25	24	11.3	5.2	.87

continued next page

TABLE 1 (continued)

Mechanical Comprehension (MC)	A power test assessing understanding mechanical principles, e.g., principles dealing with gears, levers, pulleys and hydraulics	25	19	13.5	5.2	.85
Electronics Information (EI)	A power test assessing knowledge of electricity, electronics and radio principles	20	9	11.1	4.0	.82

[a] Mean internal consistency reliability estimate for power subtests (see McNemar (1969) for computation procedure) as reported in Ree, Mullens, Mathews and Massey (1981).
[b] Parallel form reliability estimate as reported in Sims and Hiatt (1981).
[c] Mean parallel form reliability estimate as reported in Wilfong (1980).
[d] Test statistics based on data for a 20% random sample of FY 81 Army applicants described in Kass, Mitchell, Grafton, & Wing (1981).

Table 2
The Word Knowledge Subtest

This test has questions about the meaning of words. Each question has an underlined word. You are to decide which of the four possible answers most nearly means the same as the underlined word, then blacken the appropriate space on your answer sheet.

1. Small most nearly means
   A. sturdy
   B. round
   C. cheap
   D. little

2. The accountant discovered an error.
   A. searched
   B. found
   C. enlarged
   D. entered

3. Inform most nearly means
   A. ask
   B. turn
   C. tell
   D. ignore

4. The wind is variable today
   A. shifting
   B. chilling
   C. steady
   D. mild

5. Cease most nearly means
   A. start
   B. change
   C. continue
   D. stop

Table 3
The Paragraph Comprehension Subtest

This is a test of your ability to understand what you read. In this section you will find one or more paragraphs of reading material followed by incomplete statements or questions. You are to read the paragraph and select one of four lettered choices which best completes the statement or answers the question. When you have selected the answer, blacken in the correct numbered letter on your answer sheet.

1. From a building designer's standpoint, three things that make a home livable are the client, the building site, and the amount of money the client has to spend.

According to the passage, to make a home livable

A. the prospective piece of land makes little difference
B. it can be built on any piece of land
C. the design must fit the owner's income and site
D. the design must fit the designer's income

2. In certain areas water is so scarce that every attempt is made to conserve it. For instance, on one oasis in the Sahara Desert the amount of water necessary for each date palm tree has been carefully determined.

How much water is each tree given?

A. no water at all
B. exactly the amount required
C. water only if it is healthy
D. water on alternate days

3. The duty of the lighthouse keeper is to keep the light burning no matter what happens, so that ships will be warned of the presence of dangerous rocks. If a shipwreck should occur near the lighthouse, even though he would like to aid in the rescue of its crew and passengers, the lighthouse keeper must

A. stay at his light
B. rush to their aid
C. turn out the light
D. quickly sound the siren

tic differences associated with the passage, question stem, and alternatives include: total number of words, mean grade level of words, standard deviation of vocabulary level, number of polysyllabic words, location of response-relevant information in the passage, type of passage (factual, fictional, first person, second person, etc.) average length of sentence, number of sentences, number of associated questions and type of question. The paragraph selections on the PC subtests have from one to four accompanying questions. The number of distinct paragraph selections for the six operational ASVAB forms ranges from six to nine. Instructions and sample items from the Paragraph Comprehension subtest are at Table 3.

The unit of analysis for the Part 2 computations was the item. The two ASVAB forms that were examined in this work each had nine independent PC items. The probability that the ratio of number of components to items would be high for the PC subtests was recognized. The decision to proceed with the PC analyses in spite of this was based on the fact that the PC items look particularly non-parallel across forms. The results that follow for the PC items were merely suggestive.

Part One

The Development of a Model of Verbal Performance

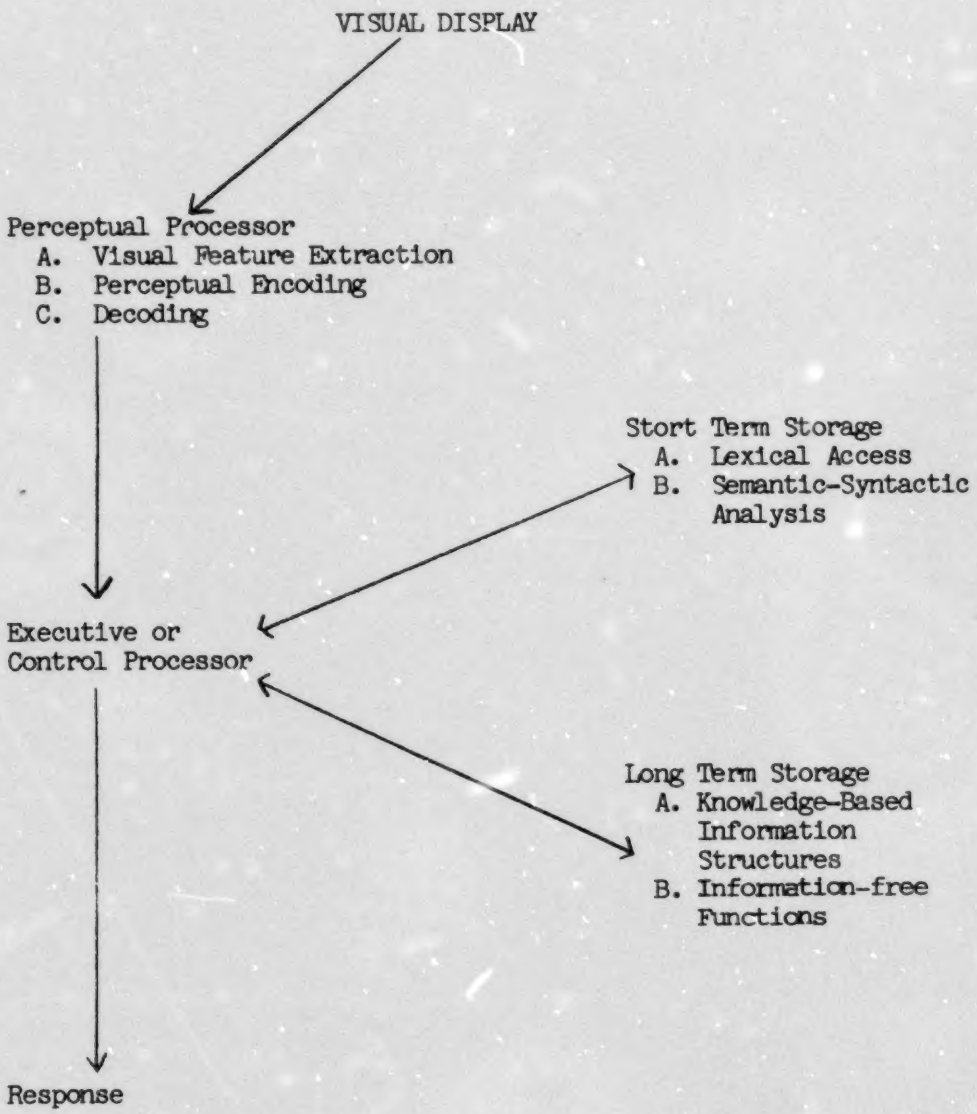
The model of verbal performance that was developed for this work borrows heavily from the paradigms of Hunt, Carroll, Frederiksen, Pellegrino, Kintsch, and others. The model describes verbal performance in the context of text analysis. The Services use the verbal subtests of the ASVAB to predict general verbal ability; the verbal items, however, directly assess only those skills used in text processing. The model, therefore, characterizes verbal performance with respect to the processes which underlie text comprehension. The model does not define a general theory of cognitive processing.

The model depicts verbal performance by five processing or storage structures. The first structure might be thought of as a perceptual processor, the second as an executive or control processor, the third as the locus of lexical access and semantic-syntactic analysis, the fourth as knowledge-based information and information-free storage, and the fifth as a response processor. Each structure is discussed below. The structures are not strictly serially or hierarchically ordered. The flow of information within the system is not necessarily sequential or parallel. A schematic of the model is at Table 4.

The PERCEPTUAL PROCESSOR is the structure that inputs stimulus information to the processing system. It includes the set of operations that converts the physical stimulus to a form that is appropriate for the task; it includes the operations that

Table 4

Model of Verbal Performance



match stimuli to appropriate grapheme and phoneme representations. The perceptual processor is characterized by three operations described by Frederiksen as: visual feature extraction, perceptual encoding, and decoding. Visual feature extraction is the operation by which different types of information about the stimulus display are extracted. The processor may select and organize information for further processing or it may ignore or deemphasize stimuli. Perceptual encoding is the operation by which information is input into the system; external stimuli are translated to internal codes. Decoding is the operation by which arbitrary physical patterns are recognized as representations of grapheme and phoneme concepts in the lexicon. These operations may be thought of as automated processes for the samples of examinees considered here. The processor may be thought of as a short term sensory storage or buffer component.

The EXECUTIVE OR CONTROL PROCESSOR is the structure that controls the flow of information in the system and has access to the various levels of memory storage. This structure (1) determines the nature of a problem, (2) has knowledge of the quality of one's competence with respect to a task, (3) selects processes for solving a problem, (4) decides on a strategy for combining these processes, (5) decides how to allocate processing resources, (6) decides how to represent the information upon which processes act, (7) evaluates how well cognitive proceses are accomplishing subgoals in terms of overall goals, and (8) makes necessary shifts in processing strategies.
This structure is analogous to Sternberg's metacomponent and to the executive processor described by Snow, Whitely, and others.

The LEXICAL ACCESS/SEMANTIC-SYNTACTIC ANALYSIS STRUCTURE is a short term storage or working memory structure. This structure can be thought of as the workbench where information is held for concentrated cognitive processing. While in working memory, information is highly available for retrieveal. It can be held in short term memory while it is being operated on or transformed by cognitive processes. There are limitations on the amount of information that can reside in working memory. One's abilities to process such information are, therefore, limited.

In the processing of text materials, a match must be made between letter strings input at the perceptual processing stage and appropriate semantic referents. Analysis in working memory is directed at attaching meaning to perceptual patterns. For phrase and sentence units, analysis is also directed at organizing these meaning elements into coherent text representations. Lexical, semantic, and syntactic knowledge is called upon in the identification of words and in phrase and sentential analysis.

Lexical Access is defined simply as the retrieval of

information about individual words from long term memory. In lexical access, grapheme and phoneme data drive the retrieval of semantic information.

Semantic-syntactic analysis takes place in short term memory; it is defined by the retrieval of knowledge-based structures and information-free functions. These structures are discussed by Hunt (1978). In semantic-syntactic analysis, the knowledge-based and information-free long term memory structures are accessed and, in the case of the information-free functions, executed in short term memory to form a semantically coherent representation of prose. Information about individual words stored in long term memory is retrieved and arranged to form a semantically coherent structure. Kintsch and van Dijk (1978) have developed a prose processing model which references the types of knowledge-based structures and information-free functions involved in semantic-syntactic analysis.

The fourth structure is a long term storage structure. This structure is the locus of KNOWLEDGE-BASED INFORMATION STRUCTURES and INFORMATION-FREE FUNCTIONS. The knowledge-based information structures represent semantic and syntactic knowledge. These structures represent the ability to deal with words and the concepts they represent. They reflect experience with and cognizance of the English language. The knowledge-based information structures are also associated with knowledge of the world and world events. These knowledge structures are mediated by verbal knowledge but represent information about the world ancillary to mastery of the English language.

The information-free functions are the operations by which information structures are transformed to equivalent structures necessary for task performance. No semantic or syntactic information is associated with these strategic knowledge structures. A distinction is made, here, between information and processes. These operators are defined by learned, stored transformation rules. Examples of information-free operators are the processes of comparing and inferring. These operators perform such functions as identifying similarities and differences among information structures, generating missing bridging information to establish semantic coherence for a text, or sorting information structures into categories.

The final structure is the RESPONSE OPERATOR. This is the structure through which appropriate actions are selected and executed. The response operator is the structure by which the examinee makes either an observable response, such as selecting one response from a set of multiple alternatives or makes an internal response such as modifying schema in long term memory.

WK and PC Item Rating Scheme

Operational definitions were developed for each of the operations/structures described above. These are documented in Mitchell (1982). The operational definitions laid the foundation for the following item rating scheme. For the Word Knowledge subtest, items were coded on five variables. They were:

A. The total word count for target string, correct response, and incorrect response strings. This count provided an index of the perceptual processing load or attentional resource allocation load imposed by an item. It was hypothesized that increases in item difficulty would accompany increases in the encoding or attentional resource load presented by an item.

B. Dichotomous coding for the Lexical Access/Semantic-Syntactic Analysis variable. Context-embedded vocabulary items were assigned a unit score. Non-embedded items received a score of zero. It was proposed that decreases in item difficulty would accompany the provision of contextual information for Word Knowledge items.

C. The Kucera and Francis word frequency score for the target word. This value indexed the probability that stored information was available for the target word. It was hypothesized that decreases in item difficulty would accompany increases in word frequency scores for the target word.

D. The Kucera and Francis word frequency score for the correct response. This value indexed the probability that stored semantic information was available for the correct response string. It was hypothesized that decreases in item difficulty would accompany increases in word frequency for the correct response.

E. Count of the high frequency-correct response/low frequency-incorrect response pairs for each item. The Kucera and Francis word frequency scores were used for the correct response and incorrect response strings to generate a count of the high-correct response/low-foil response pairs. This value indexed the relative complexity of judgements of semantic identity for correct response/target word and incorrect response/target word pairs. It was hypothesized that decreases in item difficulty would accompany increases in the number of high frequency-correct response/low frequency-incorrect response pairs.

The variables for the PC items were:

F. The total word count for the paragraph, correct response, and incorrect response strings. This count indexed the perceptual processing or attentional resource allocation load presented by an item. It was hypothesized that increases in item difficulty would accompany increases in the encoding or attentional resource load presented by an item.

G. The number of text-based inferences necessary to maintain semantic coherence as defined by Kintsch and van Dijk (1978) for the target paragraphs. The construction of text-based inferences, a controlled, mechanistic information-free function, calls upon knowledge-based information structures. A description of the rating system appears in Turner and Greene (1978). It was proposed that increases in item difficulty would accompany increases in the number of text-based inferences necessary to maintain semantic coherence.

H. A dichotomous coding for the response inference variable. Items for which the construction of an inference was necessary to link the correct response to information presented in the paragraph selection were unit coded. Coding followed Turner and Greene (1978). Again, inference construction is a controlled, mechanistic information-free function which draws upon knowledge-based information structures. It was hypothesized that item difficulty would be positively related to the construction of response inferences.

I. The number of propositions per paragraph selection divided by the number of words in the selection. Coding, again, followed Turner and Greene (1978). This value indexed the complexity of propositional structure for a paragraph selection. It was hypothesized that increases in item difficulty would accompany increases in the number of propositions suggested by each paragraph selection.

J. The number of arguments per paragraph selection divided by the number of words in the selection. Argument coding agreed with Turner and Greene (1978). Like variable four, this value indexed complexity by processing for a paragraph selection. It was hypothesized that increases in item difficulty would accompany increases in the number of different arguments presented by each paragraph selection.

K. The mean of the log transformed Kucera and Francis word frequency indices for the arguments of each selection. The value indexed the probability that stored semantic information was available for the arguments of a paragraph selection. It was hypothesized that decreases in item difficulty would accompany increases in mean word frequency scores for paragraph selections.

Obtaining ratings for the 5 variables on the 70 Word Knowledge items and the 6 variables on the 18 Paragraph Comprehension items took approximately 80 rater hours. 24 hours were needed to obtain a second set of ratings on variables G-J for the 18 Paragraph Comprehension items. Percentage agreement rates for codings on Paragraph Comprehension variables G, H, I, and J were 67%, 73%, 74%, and 92%, respectively.

Part Two

The relative effects of the cognitive processing variables on the item difficulty parameters for the verbal items of the ASVAB were estimated using the linear logistic latent trait model proposed by Fisher (1973). The model is described by Whitely and Schneider (1981) and Thissen (1982).

The model is a one-parameter latent trait model. Item difficulties or location parameters are estimated using: (1) item response data for samples of examinees, and (2) an item rating matrix reflecting structural characteristics of the items. In these analyses, the item rating matrix was the item-by-cognitive component array described in Part One. The matrix defines a set of linear constraints on the estimation of the item location parameters.

The one-parameter latent trait model estimates item difficulty in the following way:

$$P_{(x_{ij}=1)} = \frac{\exp(\xi_{ij} - \sigma_i)}{1 + \exp(\xi_j - \sigma_i)}$$

where ξ_j = the ability level for person j, and

σ_i = the difficulty for item i.

The linear logistic latent trait model consists of a set of linear constraints on item difficulty parameters, such that,

$$\sigma'_i = \sum_m (f_{im}\eta_m) + c$$

where σ'_i is a vector of difficulties, f_{im} is the item-by-cognitive component rating matrix, η_m is a vector of component parameters, and c is a normalization constant. The component parameters reflect the relative effects of the cognitive component variables on the item location parameters.
The complete linear logistic model is given:

$$P_{(x_{ij}=1)} = \frac{\exp(\xi_{ij} - (\sum_m f_{im}\eta_m + c))}{1 + \exp(\xi_{ij} - (\sum_m f_{im}\eta_m + c))}$$

When the f_{im} matrix is an identity matrix and x is set to 0, the linear logistic model is equivalent to the one-parameter latent trait or Rasch model. In this case, each item defines a separate η_m; item difficulty is the only item parameter.

Part Two analyses focused on eight samples of examinees tested on ASVAB 8/9/10. Six of the samples were FY81 applicants; two samples were FY81 Army accessions. Samples one and two were

Army applicants who were randomly selected without regard to whether they were actually admitted to the Service. Sample one was composed of 2998 applicants administered form one of the ASVAB. Sample two had 2925 records; these applicants took form two.

In addition to these two samples, subsamples of applicants defined by level of verbal ability were examined for each form. From the two samples above, the twenty percent with the lowest Word Knowledge and Paragraph Comprehension summed score were selected and the twenty percent with the highest Word Knowledge and Paragraph Comprehension summed score were selected. The N's for these low verbal and high verbal ability samples for each form are at Table 5.

Table 5

Part Two Applicant Sample Sizes

	A S V A B	
Verbal Ability Groups		
	Form 1	Form 2
Heterogeneous Ability	2998	2925
Low Ability	585	610
High Ability	604	609

These four groups were subsamples of applicant samples one and two.

Two samples of FY81 Army accessions were also selected. The samples of accessions were students enrolled in three high-density Army job training programs. The occupational specialties were:

1. 95B Military Police
2. 94B Food Service Specialist
3. 76C & 76P Equipment Records and Parts Specialist and Material Control and Accounting Specialist

Accession sample one had 400 examinees; sample two had 358 records.

Rasch item difficulties and linear logistic latent trait item locations were estimated for applicant and accession groups using

the marginal maximum likelihood procedures outlined by Thissen (1982).

For the linearly constrained latent trait model, component parameters were also calculated for each form and sample. The component estimates from the latter analyses were examined, and cognitive component variables with sizable contributions to the estimation of item difficulty values were retained in a reanalysis of the data. For each group, this third analysis was computed using the linear logistic latent trait algorithms. A reduced model was defined by the third analyses. The statistical significance of the individual cognitive component parameters was not assessed; estimation of standard errors for the component parameters is presently computationally intractable.

The adequacy of the cognitive component variables in predicting difficulty parameters for the Word Knowledge and Paragraph Comprehension items was assessed by correlating the Rasch item difficulties with the linear logistic latent trait difficulties and the reduced linear logistic latent item locations. The Rasch item difficulties, computed with one parameter per item, functioned as criterion scores for each sample. The two sets of linearly constrained logistic latent trait item locations functioned as predictor scores. The two simple correlations indexed the strength of the relation between the unconstrained and contrained item difficulties estimated in each applicant and accession group.

RESULTS

Development of the Word Knowledge Models

The full and reduced models for the Word Knowledge subtests are at Tables 6-9. The correlations between the Rasch item difficulties and the five-variable linearly-constrained item difficulty values for the Word Knowledge subtests ranged from .45 to .55. There were essentially no differences in the correlations across forms or subjects.

Reduced linear logistic latent trait models were developed for each Word Knowledge form and sample. Three sets of values were considered in the selection of cognitive component variables for the reduced models. They were: (1) the cognitive component parameters estimated by the linear logistic latent trait algorithms, (2) the intercorrelations between items ratings on the five Word Knowledge variables, and (3) the simple correlations between the item ratings and the Rasch or unconstrained item difficulty values.

Table 5

Full Model Cognitive Component Parameters (df=34)

Word Knowledge, Form One

	FY81 Applicants	FY81 Low Ability Applicants	FY81 Hi Ability Applicants	FY31 Accessions
1. Total Word Count	-.761	-1.967	.111	-.756
2. Lexical Access/Semantic-Syntactic Analysis	.481	1.133	.420	.635
3. Target Word Frequency	-.829	-1.338	-1.367	-1.231
4. Correct Response Word Frequency	-.076	-1.353	-.079	.040
5. High Frequency-Correct Response/Low Frequency-Incorrect Response Pairs	.102	.491	.166	.114
Normalization Constant	-.329	3.923	-2.782	-1.078
Simple r's, Rasch/Linear Logistic Latent Trait Item Difficulties	.48	.45	.55	.49

Table 7

Reduced Model Cognitive Component Parameters (df=34)

Word Knowledge, Form One

	FY81 Applicants	FY81 Low Ability Applicants	FY81 Hi Ability Applicants	FY81 Accessions
1. Total Word Count	.253	.251		.707
2. Lexical Access/Semantic-Syntactic Analysis			1.197	
3. Target Word Frequency	-.784	-1.048	-1.647	-1.127
4. Correct Response Word Frequency		-.830		
5. High Frequency-Correct Response/Low Frequency-Incorrect Response Pairs				
Normalization Constant	-.865	2.72	-3.891	-1.945
Simple r's, Rasch/Linear Logistic Latent Trait Item Difficulties	.44	.41	.49	.45

Table 8

Full Model Cognitive Component Parameters (df=34)

Word Knowledge, Form Two

	FY81 Applicants	FY81 Low Ability Applicants	FY81 Hi Ability Applicants	FY81 Accessions
1. Total Word Count	.415	.434	1.049	1.152
2. Lexical Access/Semantic-Syntactic Analysis	-.602	-1.674	-.720	-.916
3. Target Word Frequency	-.024	.162	-.152	-.039
4. Correct Response Word Frequency	-.445	-1.788	-.746	-.569
5. High Frequency-Correct Response/Low Frequency-Incorrect Response Pairs	-.002	.224	.190	-.050
Normalization Constant	-.685	3.047	-4.508	-1.951
Simple r's, Rasch/Linear Logistic Latent Trait Item Difficulties	.51	.46	.53	.55

Table 9

Reduced Model Cognitive Component Parameters (df=34)

Word Knowledge, Form Two

	FY81 Applicants	FY81 Low Ability Applicants	FY81 Hi Ability Applicants	FY81 Accessions
1. Total Word Count 2. Lexical Access/Semantic-Syntactic Analysis	-.472	-1.681	-.477	-.552
3. Target Word Frequency 4. Correct Response Word Frequency	-.455	-1.689	-.831	-.623
5. High Frequency-Correct Response/Low Frequency-Incorrect Response Pairs				
Normalization Constant	-.368	4.195	-4.687	-1.142
Simple r's, Rasch/Linear Logistic Latent Trait Item Difficulties	.50	.45	.51	.54

Cognitive Component Variables

The cognitive component parameters for both the Total Word Count and Lexical Access/Semantic-Syntactic Analysis variables were sizable for all examinee groups and both forms. These variables were entered singly in the reduced models because item ratings for the two variables were highly correlated. The word count for an item was positively related to whether the target word was content embedded or non-embedded. The Total Word Count variable was selected for the hetereogeneous and low verbal ability applicants and for the accessions taking form one. The Lexical Access/Semantic-Syntactic Analysis variable was included for the high ability applicants taking form one and for all examinees administered form two.

The sign of the cognitive component parameter for the Total Word count variable in the form one reduced models was positive. The cognitive component parameters for the Lexical Access/ Semantic-Syntactic Analysis variable for form two analyses were negative. The direction of effect was consistent with hypothesized relations for both variables. Item difficulty was positively related to the total number of words presented by an item. Item difficulty decreased with the provision of contextual information for the Word Knowledge items.

There was evidence of interacting effects for the Total Word Count and Lexical Access/Semantic Syntactic Analysis variables when they were entered simultaneously in the five-variable models. A possible interpretation of the interaction is that item difficulty does not increase with heavy encoding requirements when the additional lexical units provide context. Because the decrements in the item difficulty correlations from the five-variable linear logistic latent trait models to the reduced models were minimal when the variables were entered singly, these two variables were not combined in the final models.

The cognitive component parameters for the Target Word Frequency variable for form one and the Correct Response Word Frequency variable for form two were sizable. The Correct Response Word Frequency component parameter for the low verbal ability group taking form one was also large. The Target Word Frequency variable was entered in the reduced models for all groups taking form one. The Correct Response Word Frequency variable was included for the low verbal ability group taking form one and for all examinees taking form two.

Like the Total Word Count and Lexical Access/Semantic-Syntactic Analysis variables, item ratings on these two variables were highly correlated. Difficult target words were accompanied by difficult defining words. The direction of effect was consistent with hypothesized relations for these two variables in the reduced models. Words with low frequency counts were positively related to

item difficulty both for the target word and the correct alternative.

The cognitive component parameters for the High Frequency Correct Response/Low Frequency Incorrect Response variable were small for all groups. This variable was operationalized in such a way that its values were highly related to the values assigned on the Correct Response Word Frequency variable.

The parameter estimates for the cognitive component variables could not be evaluated for significance. In addition, the probabilities would be meaningless in light of the model-building procedures used. Only the relative effects of the cognitive processing variables included in the models could be examined.

The correlations between the reduced model item difficulty estimates and the Rasch item difficulty values ranged from .41 and .54. The correlations were quite similar to the correlations for the five-variable models. The models explained from 17% to 30% of the variance in the item difficulty values estimated by the Rasch models.

Form Differences

The reduced models for the two forms of the Word Knowledge subtest were judged to be conceptually similar. Both sets of models contained a variable which indexed the amount of information presented in the item and both included a variable which indexed the difficulty of the target or response words.

The Total Word Count variable is a measure of the amount of information that must be encoded, analyzed, and retained by the reader. The Lexical Access/Semantic-Syntactic Analysis variable indexes the provision of contextual information for the target word. For the Target Word Frequency and Correct Response Word Frequency variables, item ratings reflect the probability that examinees have encountered and comprehended information about individual lexical units. For both forms item ratings for the Total Word Count and Lexical Access/Semantic Syntactic Analysis variables and the Target Word Frequency and Correct Response Word Frequency variables were highly correlated.

Group Differences

Although differences in estimated Rasch and linear logistic latent trait item difficulty values were observed for examinees differentiated by level of verbal ability, no marked differences between the cognitive component parameters were noted for groups of examinees on the two forms. The composition of the models and relative magnitude of the cognitive component parameters were

comparable for hetereogeneous, low, and high verbal ability FY81 applicants and FY81 accessions.

Development of the Paragraph Comprehension Models

The results of analyses on the Paragraph Comprehension subtests were difficult to interpret. Analyses were performed on nine items for each subtest and relations were hypothesized for six cognitive processing variables. The ratios of the number of parameters to the number of items for both the full and reduced models were such that meaningful interpretation was prohibited. The results below are presented merely for completeness. The full and reduced models appear at Tables 10-13.

Cognitive component variables were selected in the same way for the reduced Paragraph Comprhension models as they were for the reduced Word Knowledge models. The cognitive component parameters for the # Propositions/# Words, # Arguments/# Words, and Mean Argument Frequency variables for form one were high for the hetereogeneous ability level applicants, the high ability applicants, and the accessions. For the low ability group, the absolute values of the Word Count, Response Inference, # Propositions/# Words, and Mean Argument Frequency component parameters were high.

The correlations between the six-variable model item difficulties and the Rasch item difficulty estimates ranged from .81 to .93 for Form One. Correlations of this magnitude were presupposed by the fact that the number of parameters was only slightly less than the number of items. For the reduced models, the correlations ranged from .67 to .84. There were no discernable differences between groups.

For Form Two the correlations between the linear logistic latent trait difficulty estimates and the Rasch item difficulties ranged from .86 to .99. The cognitive component parameters for the Response Inference, # Propositions/# Words, and # Arguments/# Words variables were high for the hetereogeneous applicant group, the low ability group, and the accession group. The Response Inference variable did not have a sizable weight for the high ability group.

The correlations between the linear logistic latent trait difficulty values for the reduced models and the Rasch difficulties ranged from .81 to .96. These models represented from 66% to 92% of the variance in the item difficulties estimated by the Rasch models. There appeared to be no group differences.

Table 10

Full Model Cognitive Component Parameters (df=8)

Paragraph Comprehension, Form One

	FY81 Applicants	FY81 Low Ability Applicants	FY81 Hi Ability Applicants	FY81 Accessions
1. Total Word Count	-.078	-1.698	4.597	.810
2. # Text-Based Inferences	.174	.153	.647	.269
3. Response Inference	.462	1.935	-.427	.660
4. # Propositions/# Words	-4.400	-4.246	-12.850	-6.855
5. # Arguments/# Words	-4.652	.410	-16.702	-6.197
6. Mean Argument Frequency	-2.339	-1.772	-6.480	-2.636
Normalization Constant	2.792	7.218	-2.074	1.922
Simple r's, Rasch/Linear Logistic Latent Trait Item Difficulties	.93	.84	.89	.81

24

Table 11

Reduced Model Cognitive Component Parameters (df=8)

Paragraph Comprehension, Form One

	FY81 Applicants	FY81 Low Ability Applicants	FY81 Hi Ability Applicants	FY81 Accessions
1. Total Word Count		-1.878		
2. # Text-Based Inferences				
3. Response Inference		1.875		
4. # Propositions/# Words	-3.393	-3.245	-4.037	-4.415
5. # Arguments/# Words	-6.265		-11.242	-8.792
6. Mean Argument Frequency	-3.529	-2.156	-6.860	-4.359
Normalization Constant	3.291	7.523	2.418	4.047
Simple r's, Rasch/Linear Logistic Latent Trait Item Difficulties	.84	.83	.67	.69

Table 12

Full Model Cognitive Component Parameters (df=8)

Paragraph Comprehension, Form Two

	FY81 Applicants	FY81 Low Ability Applicants	FY81 Hi Ability Applicants	FY81 Accessions
1. Total Word Count	-.494	-9.274	6.319	1.239
2. # Text-Based Inferences	-.033	.286	-.243	-.130
3. Response Inference	.718	3.582	.288	1.166
4. # Propositions/# Words	3.240	-33.083	30.152	11.507
5. # Arguments/# Words	-1.250	6.813	-4.880	-6.072
6. Mean Argument Frequency	-.572	.936	-1.923	-1.039
Normalization Constant	-.654	30.702	-25.807	-6.398
Simple r's, Rasch/Linear Logistic Latent Trait Item Difficulties	.99	.86	.95	.99

Table 13

Reduced Model Cognitive Component Parameters (df=8)

Paragraph Comprehension, Form Two

	FY81 Applicants	FY81 Low Ability Applicants	FY81 Hi Ability Applicants	FY81 Accessions
1. Total Word Count			1.729	
2. # Text-Based Inferences				
3. Response Inference	.739	2.940		1.199
4. # Propositions/# Words	1.740	-17.633	18.215	5.249
5. # Arguments/# Words	-.139	4.707	-.743	-3.273
6. Mean Argument Frequency				
Normalization Constant	-1.480	7.558	-13.800	-2.805
Simple r's, Rasch/Linear Logistic Latent Trait Item Difficulties	.96	.81	.87	.96

DISCUSSION

Relevance of Cognitive Processing Variables to Item Difficulty

Part 2 analyses suggested that cognitive processing variables were related to item difficulty for FY81 Army applicants and accessions on the verbal subtests of the ASVAB. The reduced linear logistic latent trait models predicted from 17% to 30% of the variance in the item difficulty values estimated by the Rasch models for the Word Knowledge items. The reduced models were predictive of the Rasch-computed item difficulties for the Paragraph Comprehension items.

Additional information about the relations between cognitive processing requirements and item difficulty might be gleaned in future research using item sets specifically developed to represent a varied range of proficiency on the individual processing variables. More sensitive assessment of individual differences on these variables and of their relevance to item difficulty might be attained with instruments constructed with special attention to assessing a varied range of ability levels on the processing variables. Evaluation, here, was possible only on the cognitive constructs represented on the operational ASVAB and only in terms of the component variance built into the test.

Further information about the relations between cognitive processing variables and item difficulty might also be gained by fitting multidimensional item response models to these data. The present analyses fit unidimensional item response models to data which were multidimensional. Both theoretical and empirical considerations attest to the multidimensionality of the data.

Determinations of the Parrallism of the Operational Forms

There was no evidence to suggest that the two operational forms of the ASVAB under investigation were not parallel. There were essentially no differences in item ratings for the five Word Knowledge and six Paragraph Comprehension variables across the two forms. The cognitive component examinations of the two forms did not point clearly to differences between forms.

CONCLUSION

The relations of cognitive processing variables to item difficulty for the ASVAB 8/9/10 Word Knowledge and Paragraph Comprehension subtests were demonstrated. Assessments of the predictive utility of these and similar constructs to success in Army training and military jobs are needed.

It is proposed that analyses of this type allow for the assessment and documentation of the contributions of cognitive processing operations, stores, and strategies to performance on industrial/organizational assessment instruments. These techniques can inform evaluations of the predictiveness and relevance of aptitude and ability measures. These methods can be used to develop item sets so that specified, training- and job-relevant cognitive processing abilities are tapped.

REFERENCES

Carroll, J. B. Psychometric Tests as Cognitive Tests: A New Structure Of Intellect. In L. B. Resnick (Ed.), The Nature of Intelligence. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1976.

Carroll, J. B., & Maxwell, S. Individual Differences in Ability. In M. R. Rosenzweig & L. W. Porters (Eds.), Annual Review of Psychology, Volume 30. Palo Alto, California: Annual Reviews 1979.

Frederiksen, J. A. Chronometric Study of Component Skills in Reading. Cambridge, Massachusetts: Bolt, Beranek and Newman, 1978.

Frederiksen, J. A. Component Skills in Reading: Measurement of Individual Differences Through Chronometric Analysis. In R. E. Snow, P. A. Federico, & W. E. Montague, (Eds.), Aptitude, Learning and Instruction, Volume 1. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1980.

Hunt, E. What Kind of Computer is Man? Cognitive Psychology, 1971, 2, 57-98.

Hunt, E. The Memory We Must Have. In R. Schank & K. Colby (Eds.), Computer Models of Thought and Language. San Francisco: Freeman, 1973.

Hunt, E. Quote the Raven? Nevermore! In L. Gregg (Ed.), Knowledge and Cognition. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1974.

Hunt, E. Varieties of Cognitive Power. In L. B. Resnik (Ed.), The Nature of Intelligence. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1976.

Hunt, E. Mechanics of Verbal Ability. Psychological Review, 1978, 85, 109-130.

Hunt, E. Intelligence as an Information-Processing Concept. British Journal of Psychology, 1980, 71, 449-474.

Hunt, E., Frost, N., & Lunneborg, D. Individual Differences in Cognition: A New Approach to Intelligence. In G. H. Bower, (Ed.), The Psychology of Learning and Motivation, Volume 7. New York: Academic Press, 1973.

BEST COPY
31

Hunt, E., & Lansman, M. Cognitive Theory Applied to Individual Differences. In W. K. Estes (Ed.), Handbook of Learning and Cognitive Processes: Introduction to Concepts and Issues, Volume 1. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1975.

Hunt, E., Lunneborg, C., & Lewis, J. What Does it Mean to be High Verbal? Cognitive Psychology, 1975, 7, 194-222.

Kass, R. A., Mitchell, K. J., Grafton, F. C., & Wing, H. Factor Structure of the Armed Service's Vocational Aptitude Battery (ASVAB) Forms 8, 9, and 10. 1981 Army Applicant Sample. Educational and Psychological Measurement, in press.

Kintsch, W. The Representation of Meaning in Memory. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1974.

Kintsch, W., & Keenan J. Reading Rate and Retention as a Function of the Number of Propositions in the Base Structure of Sentences. Cognitive Psychology, 1973, 5, 3, 257-274.

Kintsch, W., Kozminsky, E., Streby, W. J., McKoon, G., & Keenan, J. M. Comprehension & Recall of Text as a Function of Content Variables. Journal of Verbal Learning and Verbal Behavior, 1975, 14, 196-214.

Kintsch, W., & van Dijk, T. Toward a Model of Text Comprehension and Production. Psychological Review, 1978, 85, 363-394.

Kucera, H., & Francis, W. N. Computational Analysis of Present-Day American English. Providence, Rhode Island: Brown University Press, 1967.

Mitchell, K. Cognitive Processing Determinants of Item Difficulty on the Verbal Subtests of the Armed Services Vocational Aptitude Battery and Their Relation to Success in Army Training. Army Research Institute Draft Technical Report, January 1983.

Pellegrino, J. W., & Glaser, R. Cognitive Correlates and Components in the Analysis of Individual Differences. Intelligence, 1979, 3, 187-214.

Pellegrino, J. W., & Glaser, R. Components of Inductive Reasoning. In R. E. Snow, P. A. Gederico, & W. E. Montague (Eds.), Aptitude, Learning and Instruction, Volume 1. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1980.

Ree, M. J., Mullins, C. J., Mathews, J. J., & Massey, R. H. Armed Services Vocational Aptitude Battery: Item and Factor Analyses of Forms 8, 9, and 10 (AFHRL-TR-81-55). Brooks Air Force Base, TX: Air Force Human Resources Laboratory, Manpower & Personnel Division, 1981.

Sims, W. H., & Hiatt, C. M. Validation of the Armed Services Vocational Aptitude Battery (ASVAB) Forms 6 and 7 with Applications to ASVAB Forms 8, 9, and 10 (CNS 1160). Alexandria, VA: Center for Naval Analysis, 1981.

Thissen, D. Marginal Maximum Likelihood Estimation for the One-Parameter Logistic Model. Psychometrika, 1982, 47, 2, 175-186.

Whitely, S. E. Maximum Estimation of Multicomponent Latent Trait Models for Independent Processes. Technical Report, NIE-80-3, for the National Institute of Education 1980.

Whitely, S. E. Measuring Aptitude Processes with Muticomponent Latent Trait Models. Journal of Educational Measurement, 1981, 18, 2, 67-84.

Whitely, S. E., & Barnes, G. M. The Implications of Processing Event Sequences for Theories of Analogical Reasoning. Memory and Cognition, 1979, 1, 323-331.

Whitely, S. E., & Schneider, L. M. Process Outcome Models for Verbal Aptitude. Technical Report, NIE-80-1, for the National Institute of Education, 1980.

Whitely, S. E., & Schneider, L. M. Information Structure for Geometric Analogies: A Test Theory Approach. Applied Psychological Measurement, 1981, 5, 3, 383-397.

Whitely, S. E., & Schneider, L. M. Information Structure on Geometric Analogies: A Test Theory Approach. Applied Psychological Measurement, in press.

Wilfong, H. D. ASVAB: Technical Supplement to the High School Counselor's Guide. Fort Sheridan, IL: Directorate of Testing, U. S. Military Enlistment Processing Command, 1980.

BEST COPY